Exploiting spatio-temporal features of Digital Kreybig Soil Information System for the identification of regional scale soil degradation processes

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1. Abstract

The Digital Kreybig Soil Information System (DKSIS) is a 1:25.000 scale spatio-temporal soil information system due to the joint management and application of multi-temporal spatial soil information within an appropriate relational database management system and GIS environment. Implication of new sampling data collected at revisited sites made the comparison of archived and newly surveyed data possible. Thus changes in soil properties could be identified. This, in one hand, was recorded in the database updating it. On the other hand, trends were identified in soil characteristics and functions, realizing and forecasting degradation processes.

2. Introduction

Essentially, the main practical aim of soil surveys and soil maps is prediction (Leenhardt et al. 1994). The traditional tool of this information extension is the classical soil map using soil mapping units. Numerous novel methods have been developed for producing more accurate soil maps; traditional crisp soil maps, however, are still extensively applied, as they offer the most easily interpretable results for the majority of users. On the other hand, the accuracy of crisp soil maps is improvable in several ways: with the refinement of soil contours; with the subdivision of mapping units, taking into consideration smaller within patch inhomogeneities; and with the refinement of attributive information (more recent data, more precise measurement, up-to-date methodology, more appropriate classification etc.). Spatial soil information systems (SSISs) are usually based on classical soil information converting soil maps and soil profile reports into digital format. Consequently, their spatial accuracy is greatly dependent on the crisp soil maps used as raw material. However, DSM and GIS environment jointly enable much more than the simple digital reproduction of the information originating from soil surveys.

Existing SSISs concern mainly regional or national scale with corresponding cartographic scale less than 1:200,000, which corresponds to spatial resolution greater than 400 m or 16 ha in territorial units (Rossiter 2004). This is not surprising, as even soil maps for extended areas are scarcely available in larger scale. On the other hand, even if more detailed traditional soil information were available, the first initiatives on compiling a complete (e.g. national) SSIS rely on existing, generally small-scale (frequently generalized) soil maps and data. Nevertheless, more detailed SSISs are strongly expected by numerous potential users. The next step would be the level featured by a scale of 1:200,000 up to 1:20,000 (with a nominal spatial resolution of 40-400 m or 0.16-16 ha in territorial units) (Lagacherie & McBratney 2005). Even the highly developed countries are not always capable of fulfilling the expectations of the worldwide developing spatial data infrastructure (SDI) from soil information point of view, either because the existing soil databases are not exhaustive or precise enough.

3. Material and Methods

A great amount of soil information is available in Hungary due to former agrogeological surveys. The collected data are accessible in different scales: national, regional, micro-regional, farm and field level, and generally they are related to maps (Várallyay 2002). Similarly to the great majority of the world, however, large-scale, comprehensive new surveys cannot be expected in the near future. In the 1990s a great part of these, dominantly small-scale, soil related data was organized into SSISs. Actually, larger scale SSISs are also awaited by numerous fields of interests (environmental protection, land evaluation, precision farming etc.). Fitting this requirement, GIS processing of the large-scale practical soil maps is a challenging task in Hungary (Pásztor et al. 2002). As of primary importance, the GIS adaptation and digital reambulation of the 1:25,000 scale, practical soil mapping programme – hallmarked by L. Kreybig – is under construction (Szabó et al. 2005). There is much more utilizable information originating from this survey, than it was processed traditionally and published on the map series and in reports, and what is provided by simply archiving them digitally. The surplus information should be exploited by the new technologies provided by GIS and DSM. Furthermore a true SSIS can and should reach higher levels of digital processing.

3.1 The Kreybig soil survey

The national soil mapping project initiated and led by Kreybig was unique, being a national, large-scale survey based on field and laboratory soil analyses and at the same time serving practical purposes (Kreybig 1937). It was carried out between 1935 and 1951 in several stages. In the fifties, when the action was successfully completed, Hungary was the first in the world to have such detailed soil information for the whole country. These maps still represent a valuable treasure of soil information. The soil and land use conditions were shown jointly on the maps. Overall chemical and physical soil properties of the soil root zone featuring soil patches were identified for croplands. Three characteristics were attributed to soil mapping units and displayed on the maps. Further soil properties were determined and measured in soil profiles. The unique feature of the Kreybig method was that one representative and further, non-representative soil profiles occurring within the patch are attached to the soil units of the maps. These profiles jointly provide information on the heterogeneity of the area. Using representative profiles in traditional soil survey is a common solution for linking detailed soil properties originating from soil profiles and the mapping units of crisp soil map representing the pedological variability of land (Leenhardt et al. 1994). The display of non-representative soil profiles indicating within soil unit, unmappable heterogeneity was a unique approach. Traditionally, however, this special feature could not have been totally utilized due to the limits of classical cartography. New technologies make the surplus information provided by this methodology exploitable, which can be incorporated into the compilation process of KDSIS.

3.2 Conversion of analogue maps and records into digital format

The first step of the digital processing of the archives is the "simple" conversion of analogue maps and records into digital format, integrating the data available at various institutions, in different scale and processing level. The map sheets are scanned, spatial data (soil units as polygons and soil profiles as points) are vectorized; a profile database is compiled (Szabó et al. 2000). The resulted SSIS can be mainly considered as the digitally converted version of the processed map-based soil information. Nevertheless, there are various steps for increasing the spatial and thematic accuracy of soil information stored in this "raw" SSIS.

3.3 Formation of a self-consistent system

Having completed the geometric and thematic digitization of neighbouring sheets, they are fitted together solving edge correction, and then are merged. At the same time a primary desktop reambulation is carried out. This is necessary because of certain discrepancies experienced in the processed data. Although the survey methodology involved edge correlation between neighbouring sheets, some unmatching soil patches still remained. The reason for such inconsistencies might be that the available raw map material can be on different level of processing, thus the original edge matching efforts vanished in time. Further-more, discrepancies may be attributed to the temporal shift, which can occur between the independent surveys of even close areas mapped on different sheets. The original analogue maps represented individual cartographic products, which fact hid these inconsistencies; mul-tiple sheets were rarely used in parallel. Even if these types of problems had been detected by certain users they were neither reported nor used for a general improvement of the map series.

3.4 Increasing thematic accuracy within appropriate SDI

Obvious changes in land conditions not accounted for in a SSIS may stagger the applicability of the whole database, even if the mapped soil properties have not changed significantly (or generally at all) on the majority of the territory. The integration of spatial soil information within appropriate SDI can help in treating this problem. Reliability and accuracy increases by taking into consideration the changes reflected by digitally available recent information on topography and/or land use (remotely sensed images, spatial databases), which are simultaneously used within the same GIS environment. For pilot areas around the country this primary desktop update of the polygon structure has already been carried out. CLC, orthophotos and forest cadastre were used for the correction. Finalizing this stage, the elaborated KDSIS can be regarded as a true SSIS even by more rigorous critics. Nonetheless there are two further possibilities for increasing its spatial and thematic accuracy.

3.5 Spatial refinement integrating Kreybig profile methodology and SDI

The Kreybig survey used representative and non-representative soil profiles occurring within soil patches for the indication of unmappable heterogeneity of the land. KDSIS integrated with spatial themes (DEM, orthophotos etc.) on appropriate environmental factors can resolve the constraints of traditional mapping. The location of non-representative soil profiles indicates local heterogeneity in soil properties, which frequently can be identified in terrain, land use, or topography. Sharp edges, gradients occurring in these covariable spatial themes, can be used as new soil boundaries subdividing the original soil mapping units. A soil profile regarded as non-representative in its former supporting patch becomes the representative profile of the newborn entity. The spatial resolution, as well as the overall accuracy of the system can be increased by this way. This activity also contributes to the conversion of the single scale KDSIS into a multi-level SSIS with an opening to the larger scales.

3.6 Increasing thematic accuracy within appropriate SDI

Field verification/correlation completed with appropriate data collection, and the inclusion of newly accessed data into KDSIS can also increase significantly its reliability. This verification should be carried out by the reambulation of the originally mapped areas and the dug profiles accompanied with new samplings at the revisited sites for assessing current soil status. On the other hand, the appropriate management of KDSIS also makes thee elaboration of an efficient survey and sampling design possible. The stages of field reambulation are as follows:

- Identification of the representative soil profiles sampled during the Kreybig survey to be revisited, taking into consideration all available original information on the survey and recent information on the present status of the sample site.
- Navigation to the location, using the opportunities provided by field GIS.
- Testing the accessibility of the location or assignment of a new profile location.
- Determination of the representativity or assignment of a new profile location.
- Determination of the acceptability of the site as a new Kreybig profile, based on substandard profile or test boring or assignment of a new profile location.
- Detailed site characterization (with digital photo documentation), soil sampling by diagnostic layers and standard profile description for monitoring points. Incidentally further detailed and/or soil related supplementary examinations (hydrophysical properties, soil biota, nutrient status etc.).

3. Results and Discussion

The new samplings at the revisited sites make the comparison of archived (and so far stored), collected during the original survey (Keybig1K) and newly surveyed (Kreybig2K) data possible. During the current survey (reambulation) we revisited the representative sites of Kreybig 1K to determine their actual soil condition. We explored the place and made on-site examination of the soil profile and also recorded the description of environment and soil layers in new soil surveying records. We took digital pictures visually recording both the environment and soil profile itself, completing explorations and other soil properties. We collected disturbed and undisturbed soil samples from the soil layers according to the Kreybig 1K stratification and did laboratory measurements. On the basis of the results achieved in 43 surveying plots and 35 laboratory measurement datasets, we determined the physical, chemical and biological characteristics of the typical soil profiles and the genetic soil types occurring in the Bodrogköz pilot area.

During the identification of change(s) in the condition of soils the comparison of reference and actual data must be done very circumspectly. The reason for this is that the two datasets to be compared, originate from surveys done with different methodology as well as the laboratory analysis methods have been meanwhile changed (this is vigorously valid for the measurement of humus content). Taking into consideration this fact the changes in chemical reaction (soil acidification) and in salt-profile (salinization) can be reliably followed, because the spatial representativity of the data are the same in case of the evaluation both acidification and salinization data sets. During the primary evaluation all Kreybig1K and Kreybig2K data were taken into consideration, to study the main trends of possible changes. As it can be seen in Figure 1, according to pH, which can be used to characterize soil acidification, this degradation process is present in the Bodrogköz region. The distributions of data referring to the two dates shows significant difference showing chronologically an obvious drift in the direction of lower pH value ranges. Detailed description of changes in the area can be carried out by the means of comparative analysis of those point pairs, where both the identity of the location of previous and current sampling plots and their territorial representativity can be presumed. We concluded that the general changing processes of the area are the followings:

- Acidification process becomes lightly stronger and it moves on to deeper soil layers.
- In the surface layers the chemical reaction moves from the neutral-lightly acid range toward the lightly acid-acid range.

By spatial extension of data referring to soil profiles to their supporting mapping units there is a possibility to compose spatial inventory applying to state characteristics and indicators and processes as well as to illustrate their spatial distribution on maps.

4. Conclusions

The integration of traditional pedological knowledge, KDSIS and field GIS makes soil status assessment and sampling expedient, thus fieldwork becomes quick, efficient and economic. Relatively large regions can be surveyed and characterized by the updated soil properties determined in the revisited or the newly assigned representative profiles whose representativity is tested and verified in the field. Spatial extension of the information gained in point locations (both measured soil features and identified changes) can be carried out based on representativity, thus making the spatial inventory of soil related processes possible.

During its development the different stages of KDSIS provide soil information on different levels of accuracy. This kind of multilevel feature can be preserved and even utilized. Data on a lower (and consequently less precise) processing level can be produced and serviced faster, and in some cases time is a more dominant factor than spatial/ thematic accuracy. For smaller scale application "rawer" data might prove to be sufficient and at the same time more economic. Deepening KDSIS and extending its more elaborated levels also involves the opportunity of estimating the accuracy expected on the former levels.

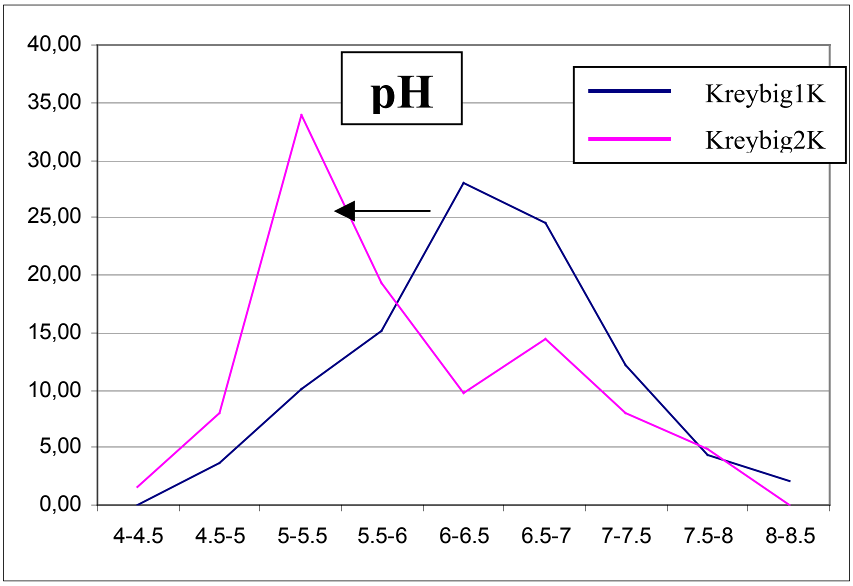

Figure 1 Changes in soil chemical properties in the Bodrogköz pilot area as shown by the histograms of the archived (Kreybig1K) and newly surveyed (Kreybig2K) data on pH ⇒ *acidification*

5. Acknowledgment

The present work was partly funded by the Hungarian National Scientific Research Foundation (OTKA, Grant No. K60896) and the National Research and Development Program (NKFP, Grant No. NKFP6-00013/2005).

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